NUSC TM 831145

NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON LABORATORY
NEW LONDON, CT 06320

Technical Memorandum

SEACAL Digital Data Processing Buoy Acoustic Performance During BERMEX-83: Quick Look Report

Date: 14 Sept 1983

Prepared by:

Peter D. Herstein

Peter D. Herstein
Physicist, 3341

Peter C. King

Peter C. King
Electronics Engineer, 3353

Approved for public release; distribution unlimited.

PREFACE

This technical memorandum was prepared under NUSC Project No. A63490, Underwater Data Buoy System, Principal Investigator, P. C. King (Code 3353). Funding was provided by the ASW Environmental Acoustic Support Project (AEAS) Naval Ocean Research and Development Activity, Code 520, C. E. Stuart, Program Manager.

The successful deployment, operation, and recovery of the SEACAL system would not have been possible without the diligent efforts of several individuals and organizations. We would like to thank Mr. Ken Dial (NORDA), Capt. Richie Lambert and the crew of the R/V ERLINE, Mr. Thomas Beaudoin (Code 3353), Mr. Ralph Austin (Code 3353), Mr. Steven Cox (Code 3353), Mr. Richard Noble (Code 3353), Ms. Sherri Herskovitz (3341), Ms. Christine Perry (3341), the personnel of the NUSC Tudor Hill Laboratory and Messrs. Jim Carnell and Nelson Messier of A&T Tech Services.

DEPARTMENT OF THE NAVY
NAVAL UNDERWATER SYSTEMS CENTER
NEWPORT, RI 02840

New London Laboratory
New London, CT 06320

IN REPLY REFER TO:

33A:PH:js
5600
Ser: 3333-13

DEC 02 1983

From: Commanding Officer
To: Commanding Officer, Naval Ocean Research and Development Activity, (Attn: C. E. Stuart, Code 520), NSTL Station, Bay St. Louis, MS 39529

Subj: NUSC Technical Memorandum; forwarding of

Encl: (1) P. D. Herstein, P. C. King, "SEACAL Digital Data Processing Buoy Acoustic Performance During BERMEX '83: Quick Look Report, NUSC TM 831145, 14 Sept 1983

1. A new multi-hydrophone digital buoy system with onboard FFT processing has been developed at NUSC. This system, called SEACAL, underwent initial at-sea engineering tests during Sept '83 as a part of the BERMEX '83 sea trials. The SEACAL buoy was subsurface moored in a deep water location near Bermuda. Over 75 hours of processed data were acquired, including both ambient noise and CW tow data. Encl (1) presents a quick look of the acoustic results.

2. SEACAL performance during BERMEX '83 has demonstrated the advanced capabilities offered by this new generation data acquisition system. It is significant to note that the rough draft of Encl (1) was completed and ready for the NORDA BERMEX '83 representative less than 36 hours after buoy recovery. Further data will be presented in the paper "Initial sea test results of a multi-hydrophone digital buoy system with in-situ FFT processing capabilities" on 11 November 1983 at the 106th Meeting of the Acoustical Society of America.

T. E. Bateman
L. FREEMAN
By direction

Copy to:

DARPA	(CDR K. Evans)
CNO	(OP-095; -098; CAPT E. Young, CDR H. Dantzler, 952D) (4)
CNM	(SPO PM-2; MAT-0723, -0724 (CAPT J. Harlett), -05 (R. Hillyer), (4)
NAVELEX	(R. Mitnick, J. Schuster, 612; R. Knudsen, PME-124) (3)
NAVSEASYSCOM	(SEA-63R; D. Porter, F. Romano, R. Farwell, J. Shooter, 63R) (5)
NAVPGSCOL	
DWTNSRDC	
NORDA	(R. Lauer, 320; R. Martin, 150; E. Chaika, W. Worsley, 530; C. Stuart (3), K. Dial (3), 520; N. Goulson, D. Millburn, 350; Library) (13)
ONT	(B. Adams, T. Kooij)
NOSC	(J. R. McCarthy, C. Persons, 7133; Library) (3)
NADC	(P. Haas; Library) (2)
NSWC	(Library) (1)
NRL	(R. Dicus, N. Yen, R. Doolittle, 5160; W. Mosely, 5120; Library) (5)
MPL	(F. Fisher)
NISC	(H. Foxwell)
DTIC (2)	
ONR	(R. Winokur, ONR-102B; CAPT E. Craig, T. Warfield ONR-220; G. Hamilton, ONR-420; J. McKisic, ONR-4250A; (5)
DIA	
ARL/UT	(N. Bedford)
NOO	(W. Jobst, J. Allen, 7310; R. Merrifield, 7311; R. Swenson, 6200; R. Christensen)(5)
A & T Tech Services	(J. Carnell, N. Messier)

Copy to:
33
33A (Cole, Herstein)
333
331
3311 (P. King)
333s

NUSC TM 831145

NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON LABORATORY
NEW LONDON, CT 06320

Technical Memorandum

SEACAL Digital Data Processing Buoy Acoustic Performance During BERMEX-83: Quick Look Report

Date: 14 Sept 1983

Prepared by:

Peter D. Herstein

Peter D. Herstein
Physicist, 3341

Peter C. King

Peter C. King
Electronics Engineer, 3353

PREFACE

This technical memorandum was prepared under NUSC Project No. A63490, Underwater Data Buoy System, Principal Investigator, P. C. King (Code 3353). Funding was provided by the ASW Environmental Acoustic Support Project (AEAS) Naval Ocean Research and Development Activity, Code 520, C. E. Stuart, Program Manager.

The successful deployment, operation, and recovery of the SEACAL system would not have been possible without the diligent efforts of several individuals and organizations. We would like to thank Mr. Ken Dial (NORDA), Capt. Richie Lambert and the crew of the R/V ERLINE, Mr. Thomas Beaudoin (Code 3353), Mr. Ralph Austin (Code 3353), Mr. Steven Cox (Code 3353), Mr. Richard Noble (Code 3353), Ms. Sherri Herskovitz (3341), Ms. Christine Perry (3341), the personnel of the NUSC Tudor Hill Laboratory and Messrs. Jim Carnell and Nelson Messier of A&T Tech Services.

ABSTRACT

A new multi-hydrophone digital buoy system with onboard FFT processing has been developed at NUSC. Acoustic data from each of eight hydrophones is digitized and real time Fast Fourier Transformed by the buoy's micro-processor. Complex and ensemble averaged spectral results are then written onto a high density digital cartridge tape. An instantaneous dynamic range of at least 72 dB is available over the frequency band 4-350 Hz. The first open ocean test of the system occurred in September 1983 at a deep water location near Bermuda as a part of the BERMEX '83 sea trials. The system performed nearly flawlessly and was recovered intact. Over 75 hours of acoustic data were acquired, including both ambient noise and CW tow measurements. This technical memorandum presents a quick look review of the acoustic results of the sea test.

List of Figures

INTRODUCTION

The first open ocean test of the SEACAL autonomous digital buoy system was conducted during the period of 8-11 September 83 as a part of BERMEX '83 (ref 1). The system was deployed at 1335Z on 8 September 83 in deep water near the Bermuda Islands, and was recovered completely intact at 2000Z on 11 September 83. The system performed nearly flawlessly and over 75 hours of acoustic data were acquired. All eight hydrophones operated successfully. This technical memorandum presents the acoustic results obtained from a review of the data on 12 September 83.

BACKGROUND

The SEACAL buoy system as configured during BERMEX '83 consists of a vertical array of eight hydrophones and a data acquisition/digital processing package. The array is configured with a geometric spatial taper over the band 150-300 Hz and has an acoustic aperture of 25.4 m. Data from each of the eight hydrophones is digitized and Fast Fourier Transformed. The distance between frequency bin centers is 2.0 Hz. Data is acquired over the band 4-350 Hz. Spectra are computed for all eight hydrophones at a rate of 1.2 spectra per minute for each hydrophone. Ensemble averaged power spectra are written to a digital tape cartridge every 7.8 minutes and represent a 6.8 minute period of averaging. Also, for post-processing beamforming, complex spectra are written once each 7.8 minutes. One block of data consists of the ensemble summed power spectra for each of the 8 hydrophones over the 6.8 min period, plus one set of complex spectra for each hydrophone. After successful recovery of the SEACAL buoy, the cassette containing the processed data is removed for post-processing on a Hewlett-Packard-85 desktop computer. The system has been calibrated end-to-end so that ensemble averaged results are displayed in dB ref uPa/Hz$^{1/2}$, with the system normalized to a CW tone observed with 1 Hz resolution. In addition to acoustic data, depth and inclination sensors were employed.

SCENARIO

The system was deployed at 32°15'N, 65°22'W. This location is 27.7 nmi west of Gibbs Hill Lighthouse, Bermuda. The water depth is approximately 4600 m. The buoy system was subsurface moored such that the array was 2030 m above the sea floor. During part of BERMEX '83, CW signals were recorded. The CW source was an HX-90 transducer in a tow body. Two frequencies were projected: 148 Hz at 166 dB ref 1 uPa @1m and 290 Hz at 180 dB uPa @1m. The source depth was nominally 91m. Two tows were conducted: (1) over the SEACAL system, and (2) closing from approximately 58 nmi west of the buoy.

DATA EXAMINED FOR QUICK LOOK

Only ensemble averaged spectra from individual hydrophones have been reviewed so far. Three sets have been examined: (1) CW tow over the system, (2) CW tow closing from 58 nmi, and (3) ambient noise.

About 75 individual hydrophone spectra have been plotted and listed to obtain a quantitative flavor of the data. This represents only about 1% of the total data acquired.

CW TOW OVER THE SEACAL SYSTEM

From 1901Z to 2026Z on 9 September 83 the HX-90 was towed in the vicinity of the array. Figure 1 presents the ship track for the portion of the tow most directly over the array. Figure 2 presents the ensemble averaged spectrum over the period 2000.58Z to 2007.37Z. Table A (Page 12) presents the tabulated listing of this spectrum. The two tones at 148Hz and 290Hz can be clearly observed. The additional tonal at 250Hz is believed to be associated with the R/V ERLINE which was towing the source (ref 2). Spectra from the other hydrophones were similar. To examine variations from hydrophone to hydrophone, spectral levels of the two tonals were each plotted for all eight hydrophones. Figure 3a shows the results for the 148Hz tone during the 1953.16Z to 1959.57Z time period, while Figure 3b shows the results at 290Hz for the same time period. Figure 4a presents the received levels of the 148Hz during the next time period of 2000.58Z to 2007.37Z, and figure 4b presents the results at 290Hz for that time period. For the 2008.38Z to 2015.16Z time period, Figure 5a shows the results at 148Hz while Figure 5b shows the results at 290Hz. Figures 3a, 4a, and 5a have been combined in Figure 6a to show the results at 148 Hz for the 22 minute period when the source was nominally over the SEACAL array. Similarly, Figure 6b presents the composite results for 290 Hz. Several observations can be made: (a) during any given 6.8 min average, the maximum variation across the hydrophones is less than 5dB, (b) there is less variation over time in the 290Hz data than in the 148Hz data, and (c) based on eyeball estimates, there is about an 18dB difference between the 290Hz and 148Hz results. All eight hydrophones appear to be operating properly.

CW TOW FROM 58 nmi WEST OF THE SEACAL SYSTEM

This tow commenced at 0240Z on 10 September 83 and finished at 1425Z the same day. The tow track is shown in figure 7. For the first 11 hours the R/V ERLINE towed radially toward the array at a nominal speed of 5 knots. Figure 8 presents ensembled averaged spectra of hydrophone #1 for the period 0230.45Z to 0237.32Z, immediately prior to the start of the tow. No tones can be observed at either 148Hz or 290Hz. At 0240Z the source was turned on at a range of approximately 58 nmi from the SEACAL system. Figure 9 shows the spectrum of hydrophone #1 for the time period 0238.35Z to 0245.23Z. Note the 290Hz tone now apparent with about a 22dB SNR. Figure 10 shows spectra from each of the eight hydrophones for the next time period of 0246.26Z to 0253.17Z. Fluctuations of about 5dB are observed for the 290Hz tone. Also, the 148 Hz tone can be more readily observed. Between 10-100 Hz all the hydrophones exhibit nearly identical spectra. This could be due to distant shipping.

The 148Hz tone is only intermittently observed until the source range decreases to about 40 nmi. Figure 11 shows the results for hydrophone #1 during the period 0642.02 to 0648.54Z, representing an

estimated average range of 39 nmi. Both tones can be easily observed above the background. There is a 15.4 dB difference between the received levels of the two tones. A point to note is the asymmetry of the spectral values immediately adjacent to the two source tones. Given the 2Hz bin separation and Hanning weighting, the spectral values immediately adjacent to the tones would be symmetric if the tones were exactly on bin centers. Interpolation shows that the received frequencies are in fact slightly higher than 148Hz and 290Hz. Since the source is being towed toward the SEACAL, an upwards Doppler shift is to be expected. At a tow speed of 5 knots, a shift of .5 Hz would be predicted for the 290Hz tone, i.e., the received frequency would be 290.5Hz. Figure 12 shows results for hydrophones at an estimated range of 10 nmi, both tones are again observable. No explanation is currently available for the large ambient noise between 10 and 20Hz. Figure 13 presents hydrophone #1 for the period 1336.22Z to 1343.00Z, the estimated source range being less than 1 nmi. Between the two source tonals, note the emergence of the 250Hz lump associated with the R/V ERLINE. Not surprising, this figure is very similar to Figure 1, when the source was nominally over the array.

Spectra of hydrophone #1 were plotted for 26 of 90 time periods available during this CW tow. By converting the times to ranges and reading the received level at 290Hz from the tabular listing provided with each plot, a graph of the received level of the 290Hz tone as a function of range was derived and is shown in Figure 14. Although it is tempting to convert this plot to propagation loss by subtracting received level from source level, further precise verification of the actual source levels used is required.

AMBIENT NOISE

A major design goal of acoustic data acquisition systems is that their system noise floor be well below the ambient noise levels expected in a quiet type area. Recall that ambient noise was measured just prior to the commencement of the CW tow from 58 nmi west of the SEACAL system. Figure 15 shows this same result (solid line) compared with system noise measured prior to deployment of the system. System noise is measured by shorting the analog system input. Except for a few tonals, systems noise is in general 15dB or more below the ambient noise measured for this example. Figure 16 shows this case compared with archival measurements of Perrone (ref 3). Note that results are with respect to a 2.9Hz band. His results are the mean of measurements from a receiver located 4.4 km below the ocean surface when the wind speed is 0-2.5 knots. Recall that the 8 SEACAL hydrophones were deployed over a 25 m vertical aperture. Figure 17 shows the spectra of each of the hydrophones for the same time period as the previous figure. In the 10-100 Hz region the spectra between the 8 hydrophones are structurally very similar, while above 100 Hz the spectra become more independent of each other. A maximum variation on the order of 5dB between the ambient levels of the hydrophones is observed for frequencies above 150 Hz. Figure 18 presents a second measurement of ambient noise. This measurement was acquired earlier than the previous figure, during the period of 0631.43Z to 0638.26Z .

on 9 September 83. Again, hydrophone #1 is presented but results are similar for the other phones. The solid line represents the measurement results while the Ø symbol represents the same archival comparison used in Figure 16.

CONCLUSIONS

The SEACAL system successfully acquired and FFT processed over 75 hours of acoustic data. All eight hydrophones functioned correctly. System noise was well below measured ambient noise. A 290 Hz CW tone at a nominal level of 180 dB ref 1 uPa@1m was detected continuously over a 58 nmi tow. A 148 hz tone with a nominal level of 166 dB ref 1uPa@1m was continuously detected out to 40 nmi, and then intermittently detected out to 58 nmi. When the R/V ERLINE was positioned near SEACAL, spectral energy centered at 250 Hz was observed. The SEACAL system was recovered intact. Only 1% of the data has been examined so far, and only ensemble averaged hydrophone power spectra were reviewed. The quantity and quality of the data warrant further analysis.

REFERENCES

1. Ocean Programs Management Office, "Exercise Plan for BERMEX '83," NORDA AEAS Report No. 180, Aug 1983 (UNCLASSIFIED).

2. M. Ricciuti, personal communication.

3. A. J. Perrone, "Summary of a One-Year Ambient Noise Measurement Program off Bermuda," NUSC TR 4979, 1 April 1976 (UNCLASSIFIED).

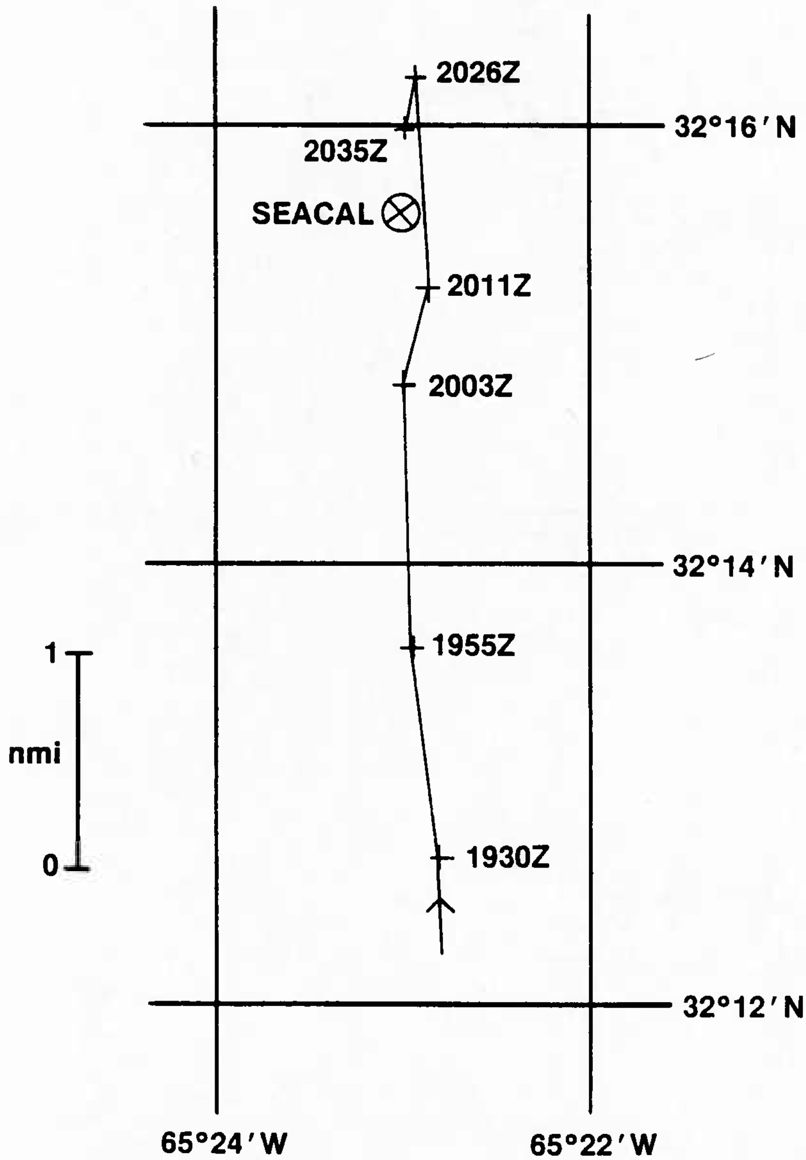
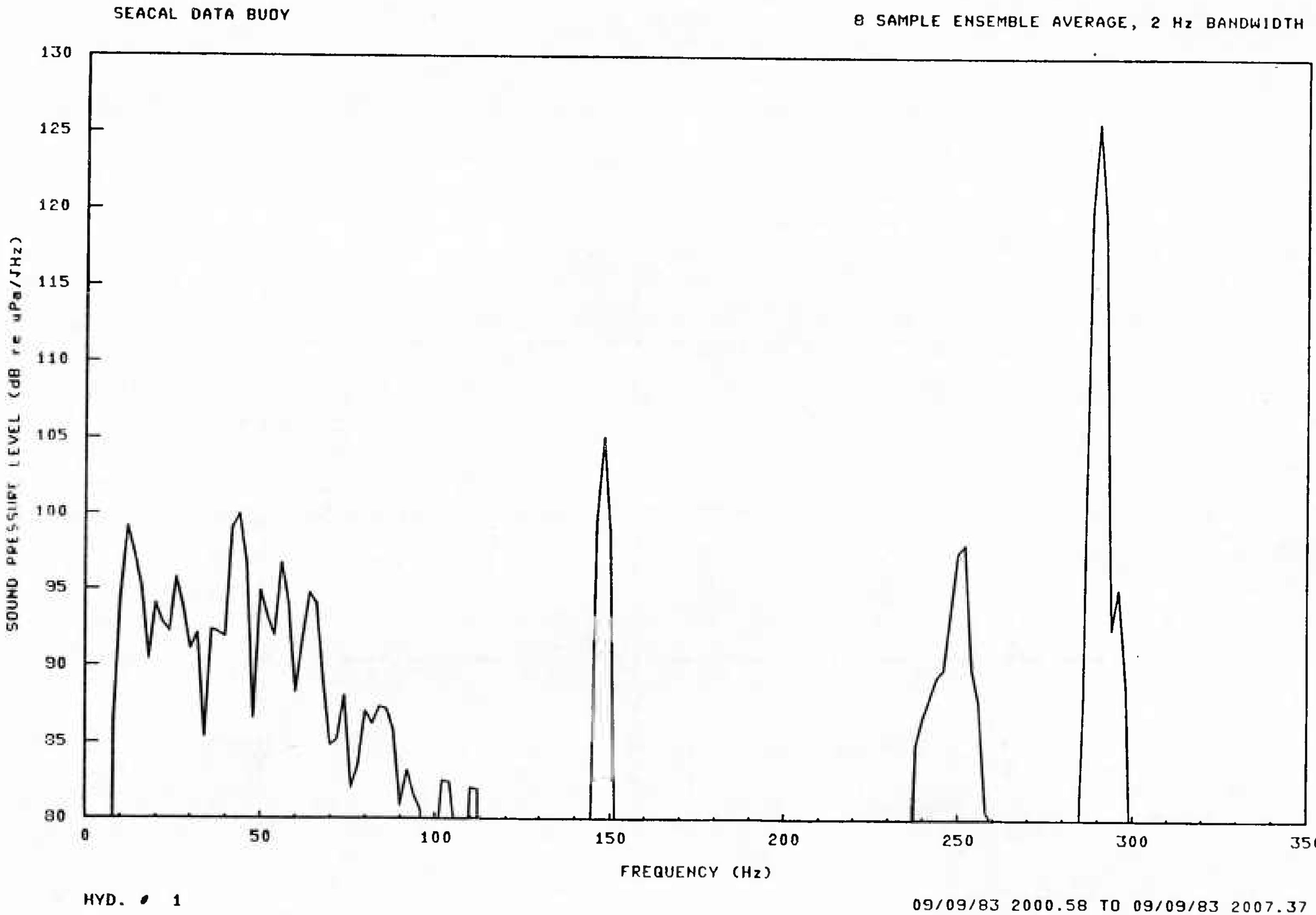


Figure 1

Ship Track of CW tow over SEACAL for the period circa 1930 to 2030 Z on 09/09/83



Spectrum of hydrophone #1 for the period
2000.58 to 2007.37 Z on 09/09/83

Figure 2

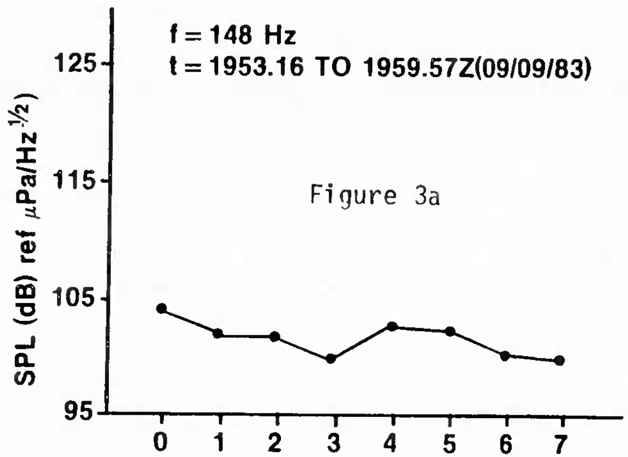
SEACAL DATA BUOY

Naval Underwater Systems Center
BERMEX '83
HYD. # 1 HYD SENS -178.5 dB re 1V/uPa
TAPE BLOCK # 32B0 <HEX> 09/09/83 2000.58 TO 09/09/83 2007.37
G = 0 P@100 = 46.03
O.F. = 0 S.F = 46 CAL FILE CREATED 08/25/83

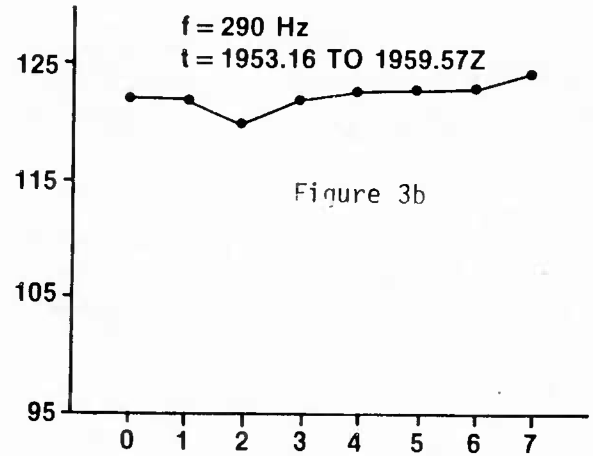
TABLE A

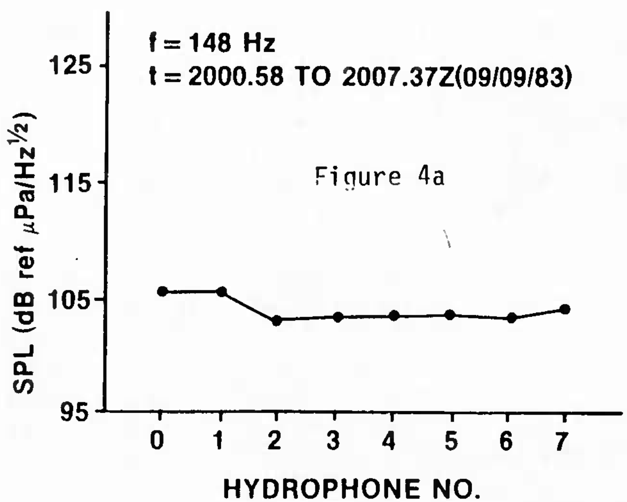
FREQ	SOUND PRESSURE LEVEL (dB re uPa/√Hz)									
0	110.43	101.25	-23.33	-30.86	86.19	94.51	99.09	97.34	95.09	90.39
20	94.03	92.75	92.18	95.74	93.75	91.06	92.06	85.32	92.32	92.14
40	91.83	99.04	99.92	96.70	86.55	94.87	93.18	91.91	96.70	94.11
60	88.23	91.56	94.74	93.98	88.82	84.77	85.18	88.00	81.93	83.50
80	86.99	86.20	87.30	87.16	85.77	80.85	83.14	81.54	80.47	-46.12
100	77.19	82.46	82.37	78.56	73.65	82.00	81.86	-47.09	73.17	73.15
120	75.93	72.79	72.73	79.61	72.50	72.42	72.26	-48.25	72.07	78.97
140	74.88	76.56	74.68	99.38	105.06	98.74	71.20	79.64	77.11	71.03
160	70.92	-49.55	-49.65	76.70	-49.83	73.51	73.44	73.39	78.08	76.24
180	-50.29	76.03	79.97	77.66	72.81	-50.67	74.48	69.58	75.52	75.46
200	-51.07	72.31	69.26	78.73	79.11	78.57	-51.46	68.90	73.59	73.54
220	76.47	68.63	-51.86	68.49	73.22	73.13	-52.13	76.00	68.17	84.82
240	86.65	87.92	89.28	89.79	93.61	97.40	97.96	89.82	87.65	80.52
260	79.76	-53.01	-53.07	-53.12	-53.16	67.20	71.92	75.55	73.07	70.03
280	76.97	-53.49	72.90	88.16	119.80	125.66	119.60	92.42	95.05	88.82
300	72.53	74.24	69.42	78.41	74.12	66.28	69.24	70.95	-54.26	66.14
320	75.66	75.16	73.16	66.21	-54.12	-53.99	66.57	66.79	-53.37	-53.02
340	-52.65	71.22	68.67	-51.22	-50.65	-50.06				

Spectral levels of the received 148 Hz tone for the eight SEACAL hydrophones during the period 1953.16 to 1959.57 Z on 09/09/83

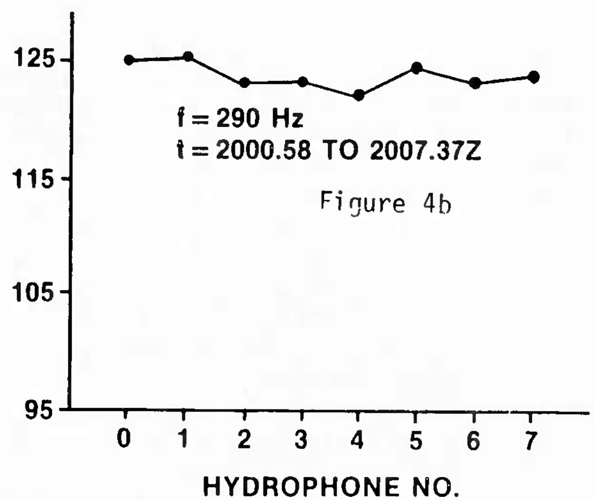


Spectral levels of the received 290 Hz tone for the eight SEACAL hydrophones during the period 1953.16 to 1959.57 Z on 09/09/83





Spectral levels of the received 148 Hz tone for the eight SEACAL hydrophones during the period 2000.58 to 2007.37 Z on 09/09/83



Spectral levels of the received 290 Hz tone for the eight SEACAL hydrophones during the period 2000.58 to 2007.37 Z on 09/09/83

Spectral levels of the received 148 Hz tone for the eight SEACAL hydrophones during the period 2008.38 to 2015.16 Z on 09/09/83

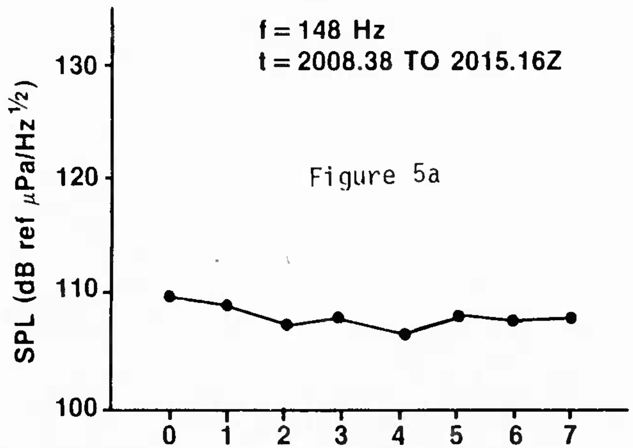


Figure 5a

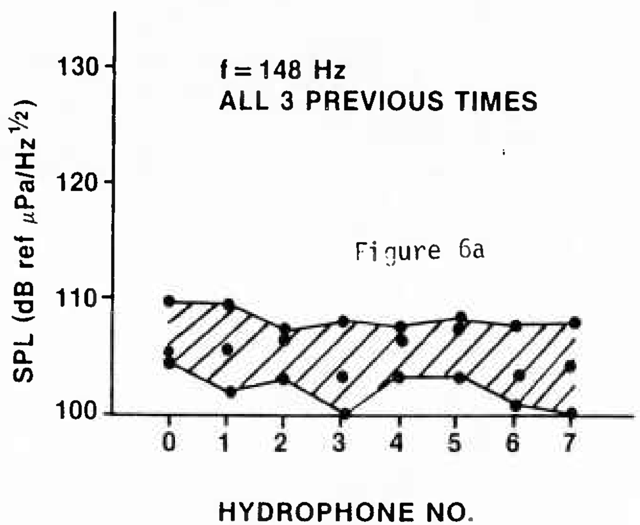


Figure 6a

Spectral level distribution of the received 148 Hz tone for the eight SEACAL hydrophones during the period 1953.16 to 2015.16 Z on 09/09/83

Spectral levels of the received 290 Hz tone for the eight SEACAL hydrophones during the period 2008.38 to 2015.16 Z on 09/09/83

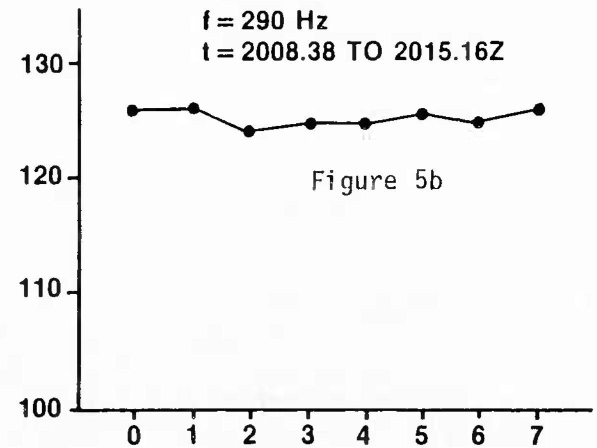


Figure 5b

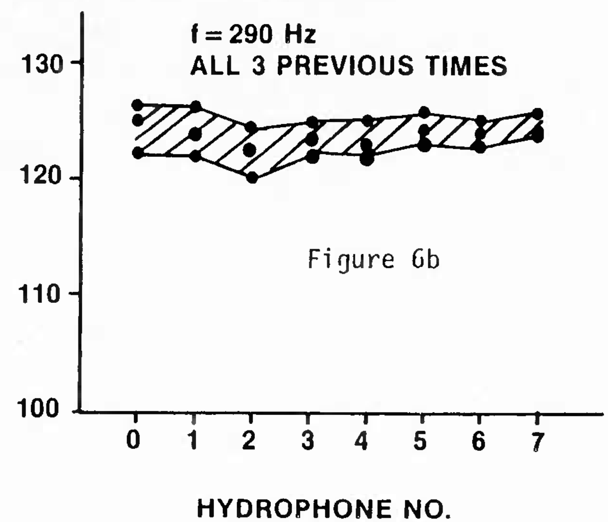
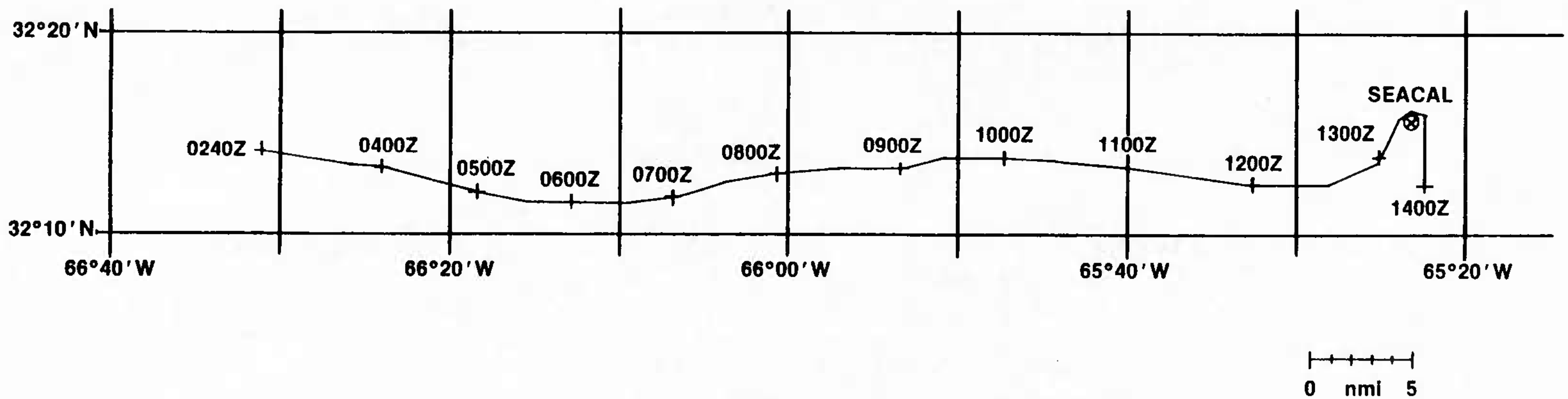


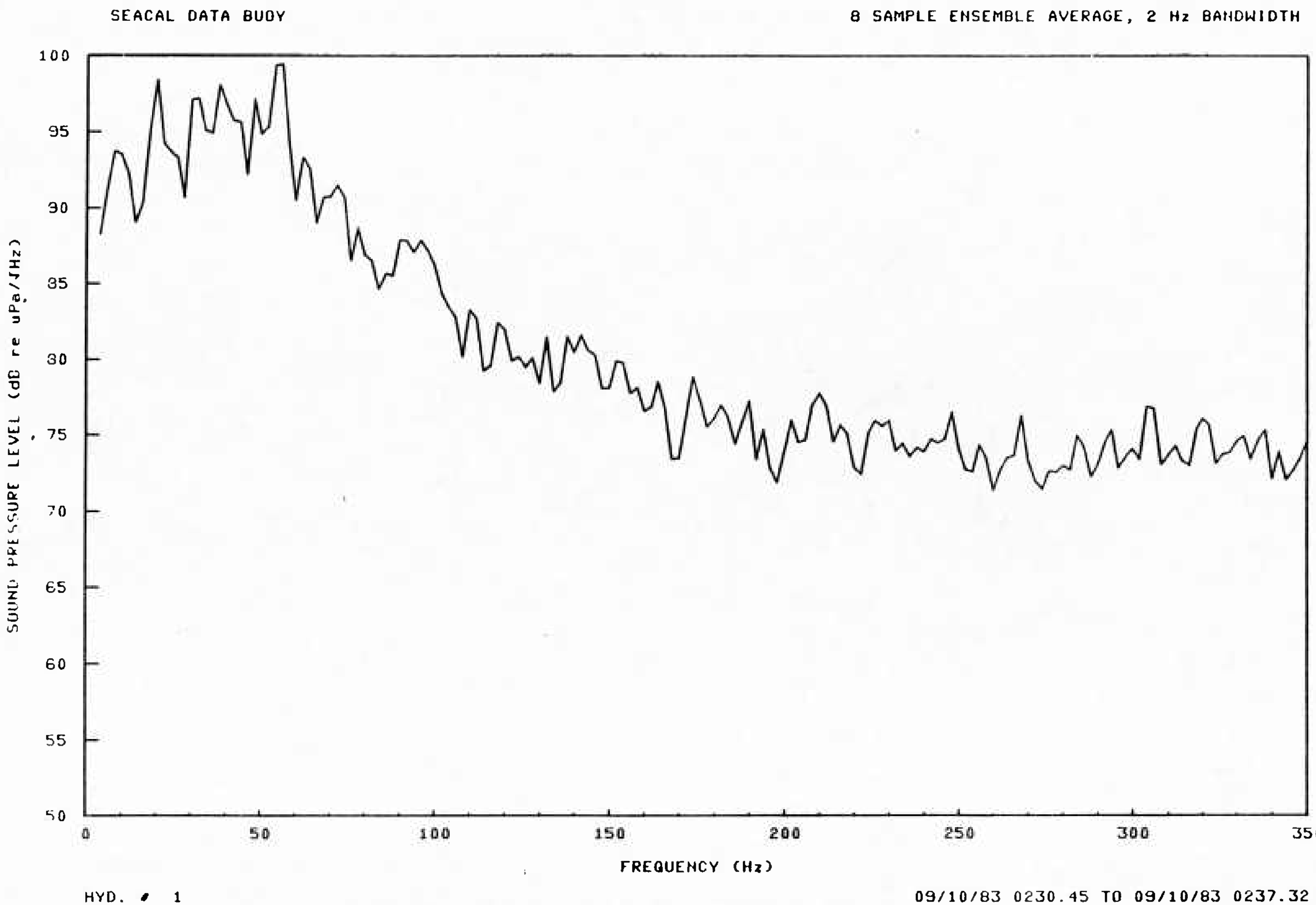
Figure 6b

Spectral level distribution of the received 290 Hz tone for the eight SEACAL hydrophones during the period 1953.16 to 2015.16 Z on 09/09/83



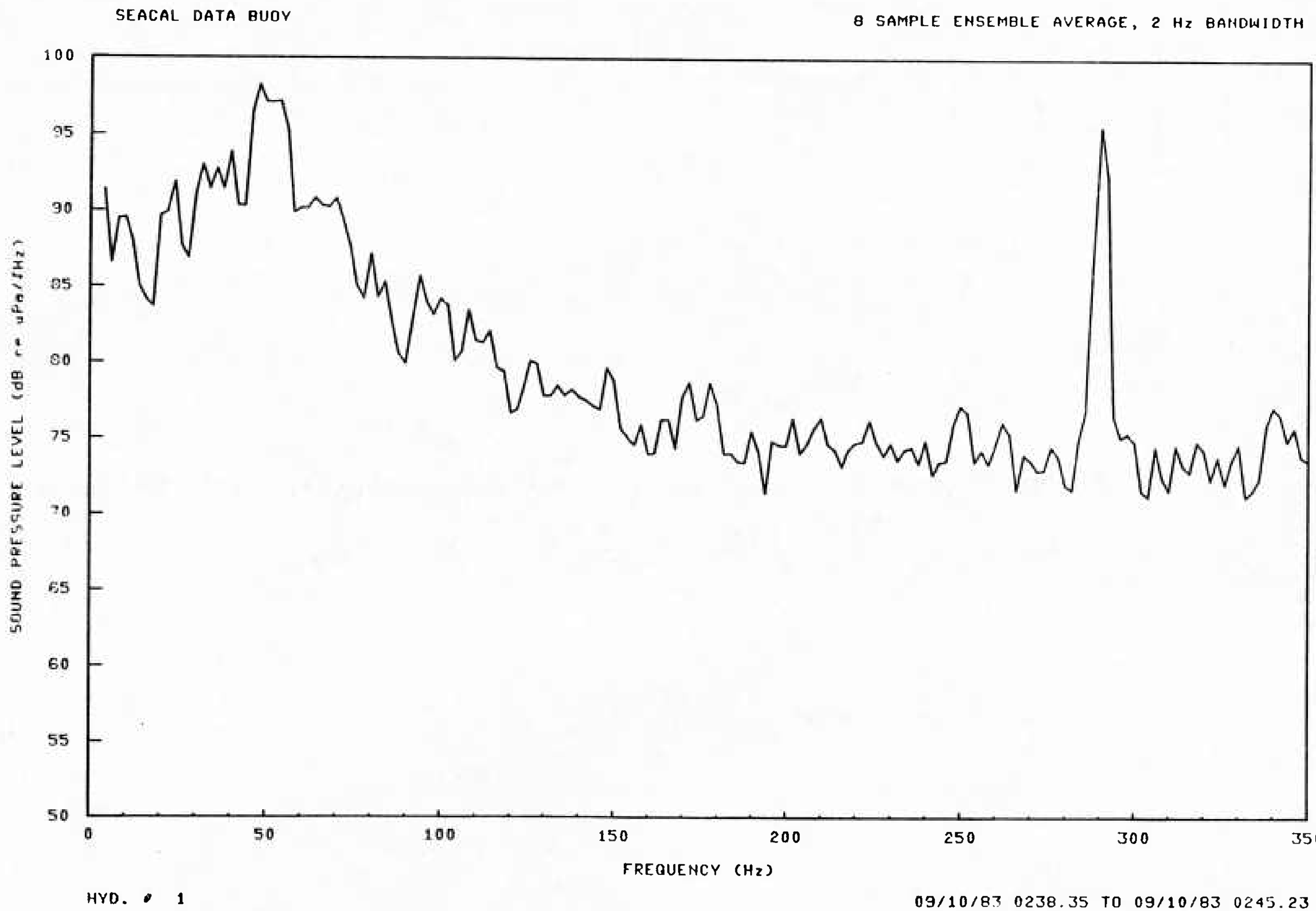
Ship Track of the CW tow commencing 58 nmi west of SEACAL for the period 0240 Z to 1400 Z on 09/10/83

Figure 7



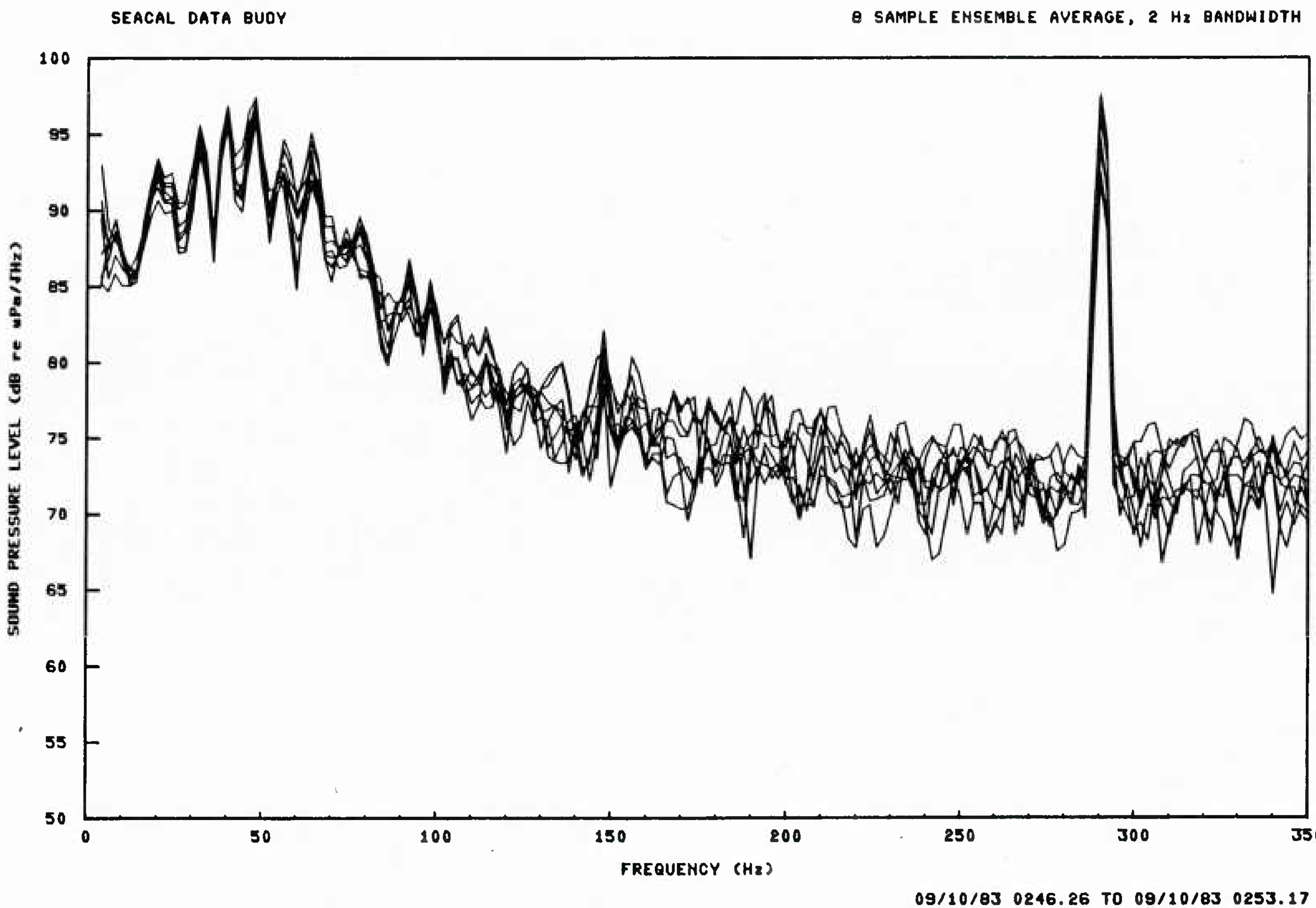
Spectrum of hydrophone #1 immediately prior to commencement of CW tow from 58 nmi west of SEACAL

Figure 8



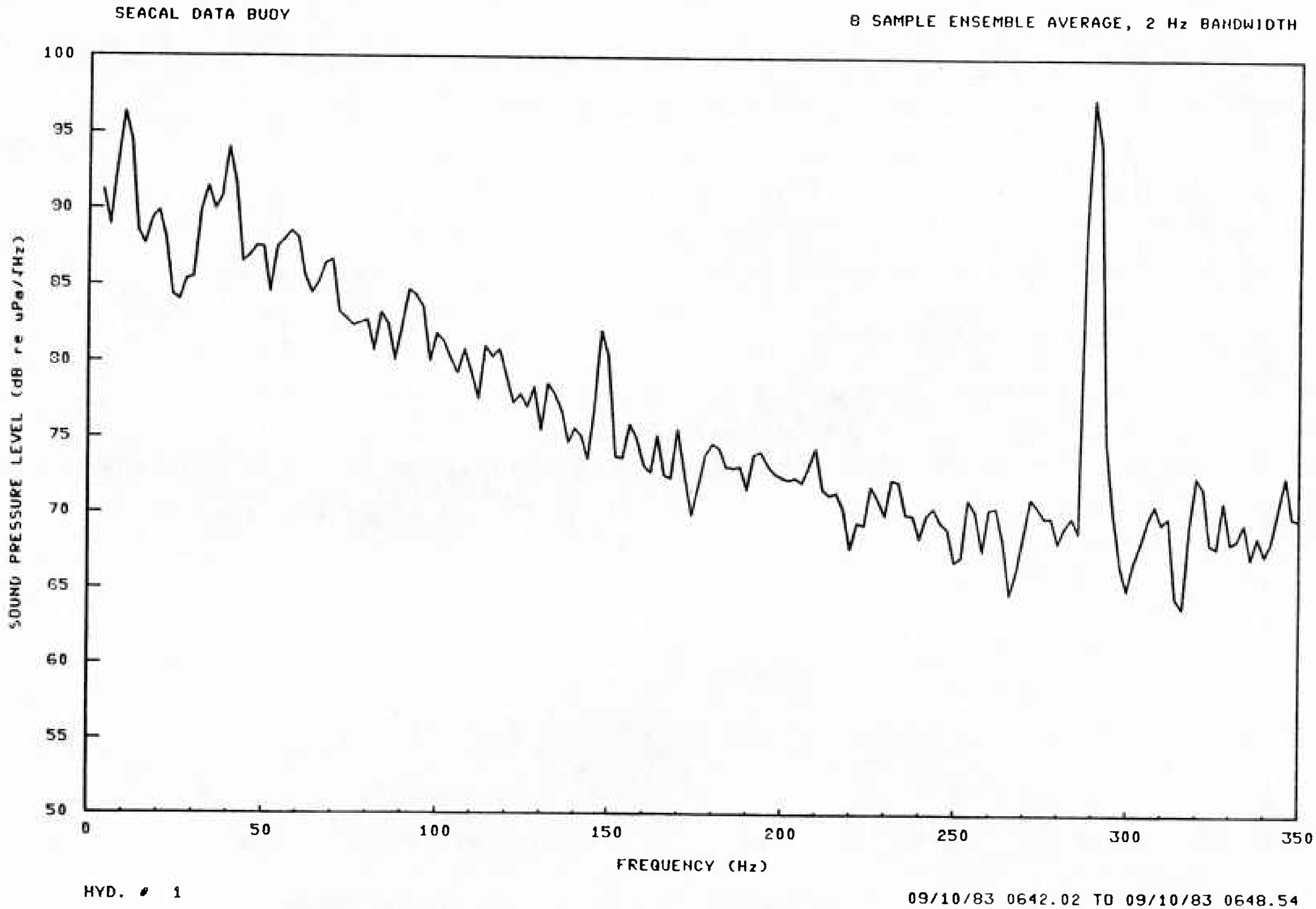
Spectrum of hydrophone #1 with the CW source 58 nmi west of SEACAL

Figure 9



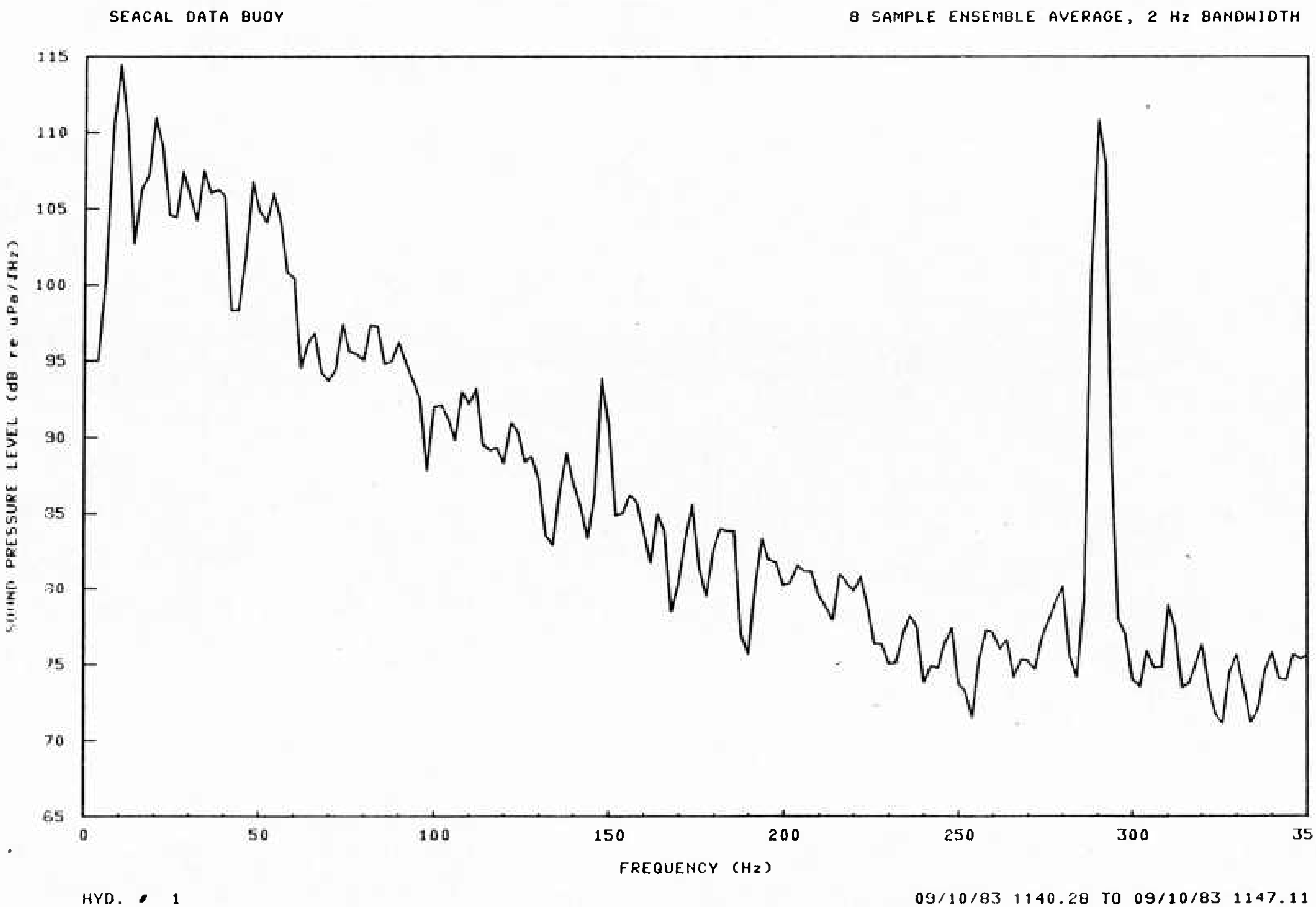
Spectra of the eight SEACAL hydrophones with the CW source 57 nmi west of SEACAL

Figure 10



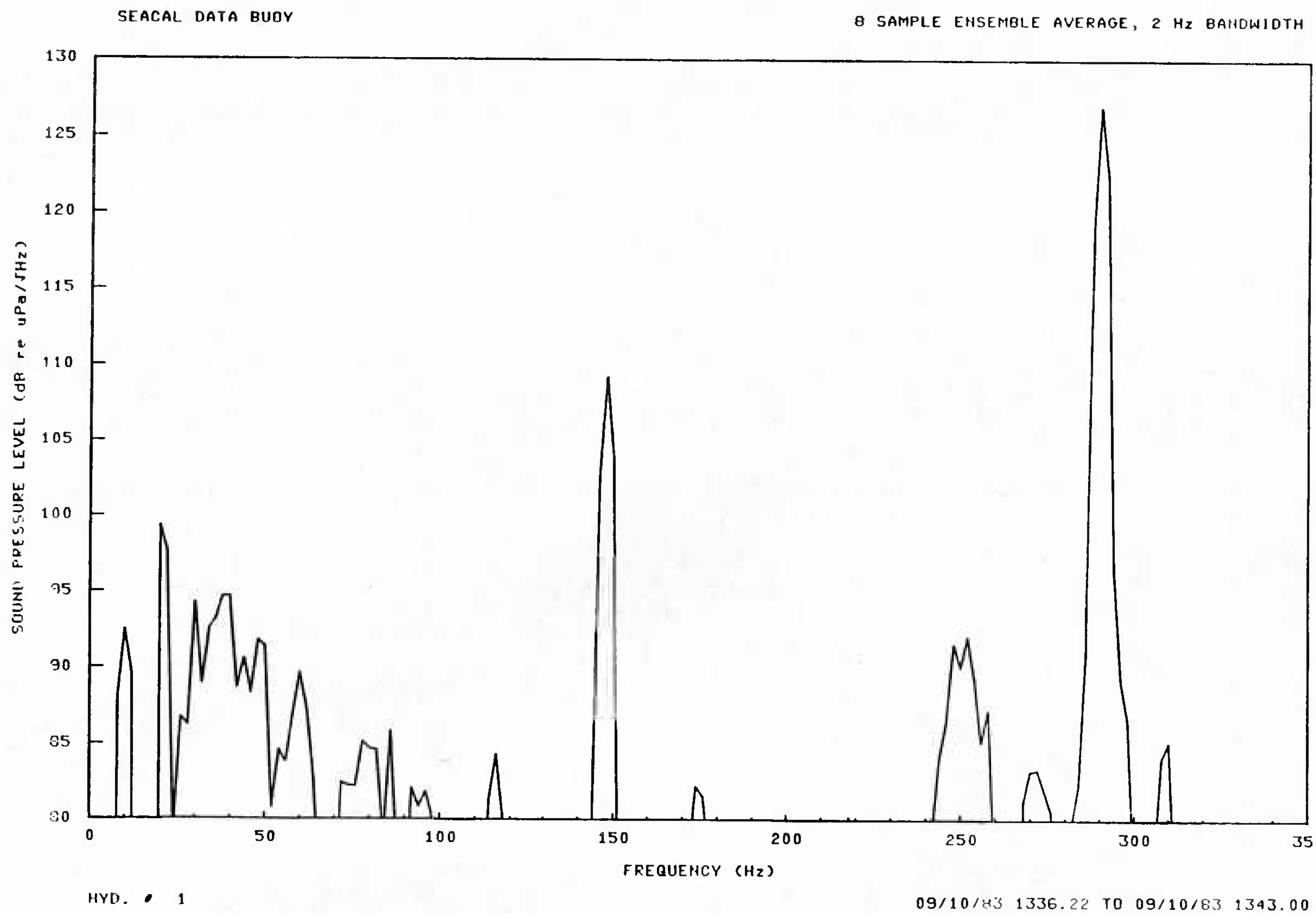
Spectrum of hydrophone #1 with the CW source
39 nmi west of SEACAL

Figure 11



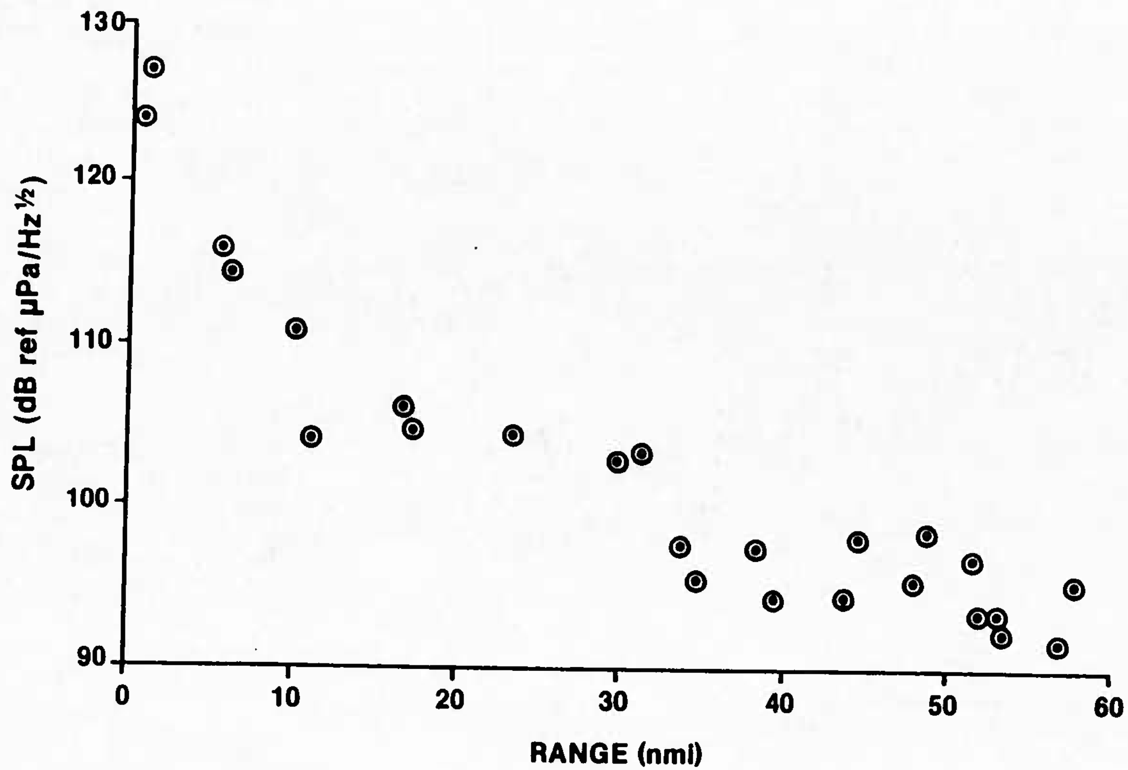
Spectrum of hydrophone #1 with the CW source
10 nmi west of SEACAL

Figure 12



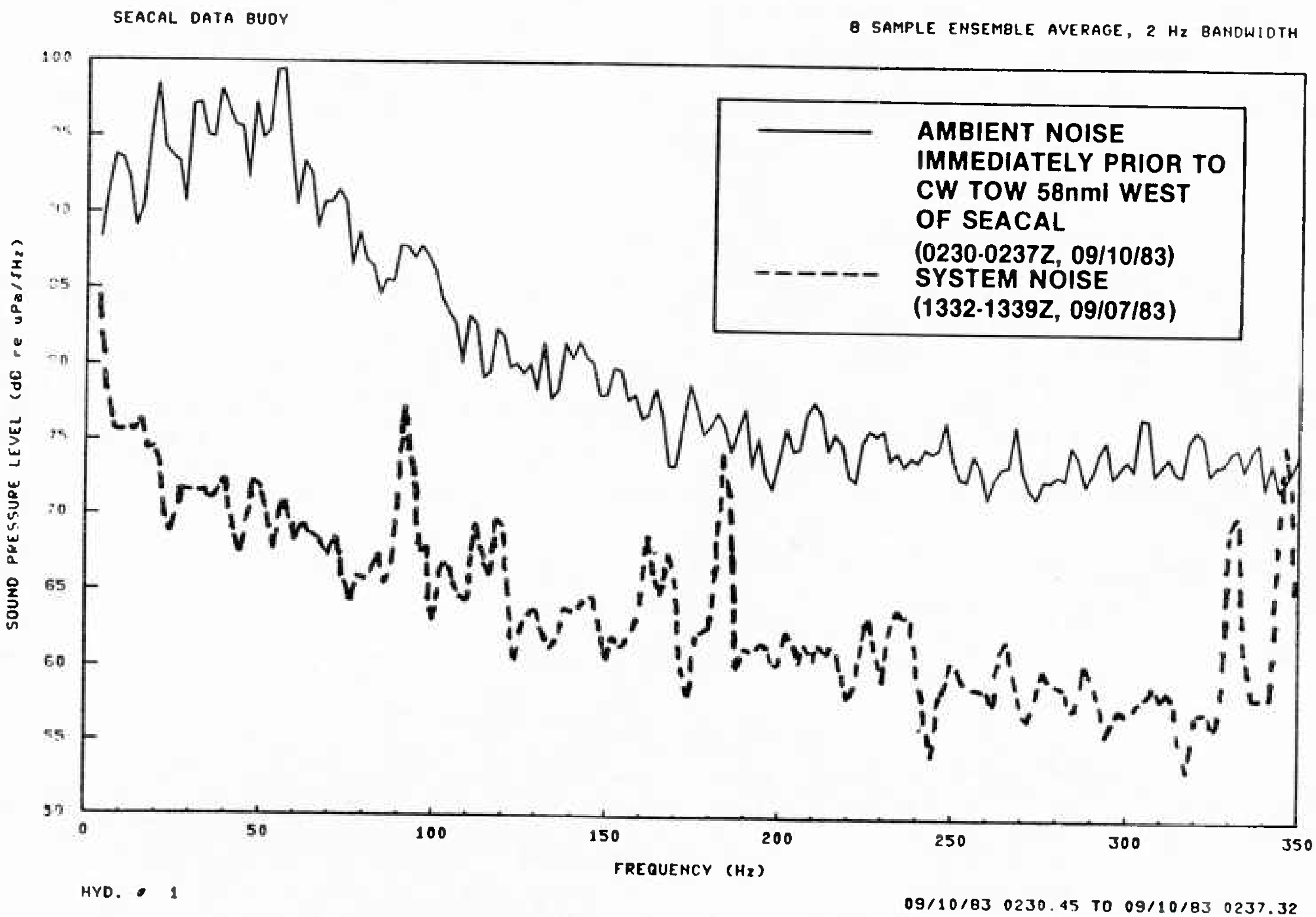
Spectrum of hydrophone #1 with the CW source
1 nmi southeast of SEACAL

Figure 13



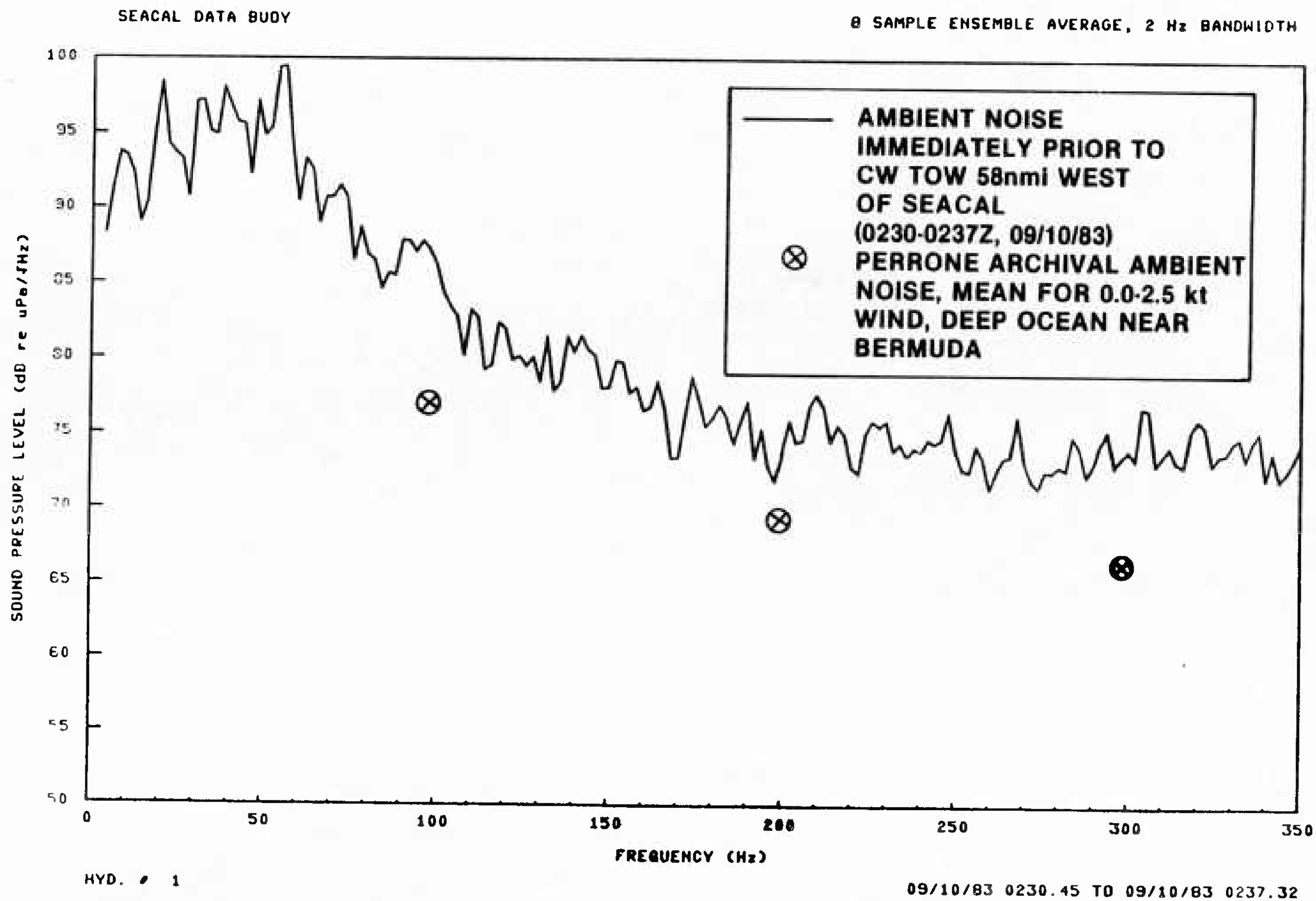
Received level of the 290 Hz tone as a function of range for hydrophone #1 during the 58 nmi CW tow

Figure 14



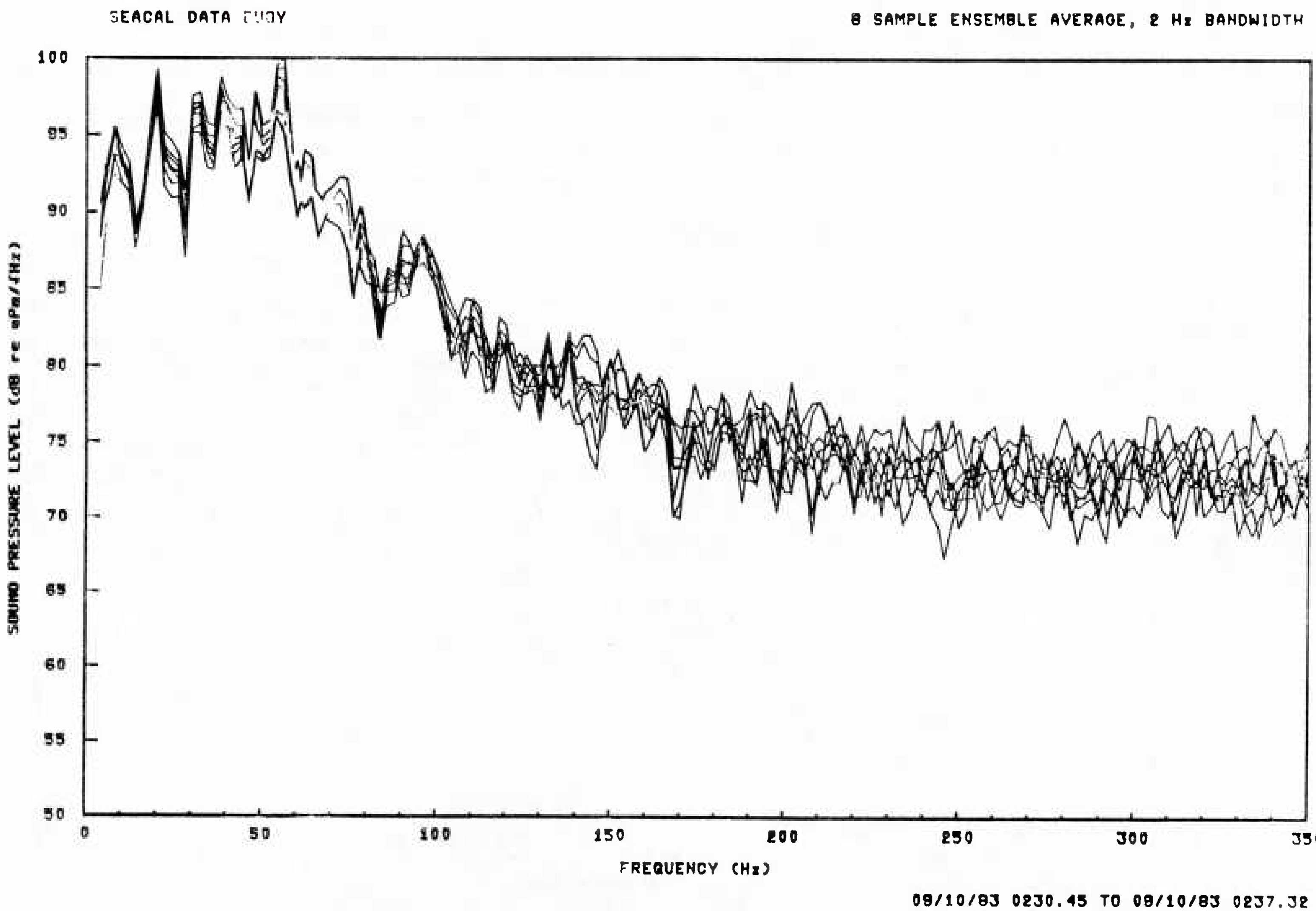
Ambient noise received on hydrophone #1 immediately prior to the CW tow 58 nmi west of SEACAL compared with system noise

Figure 15



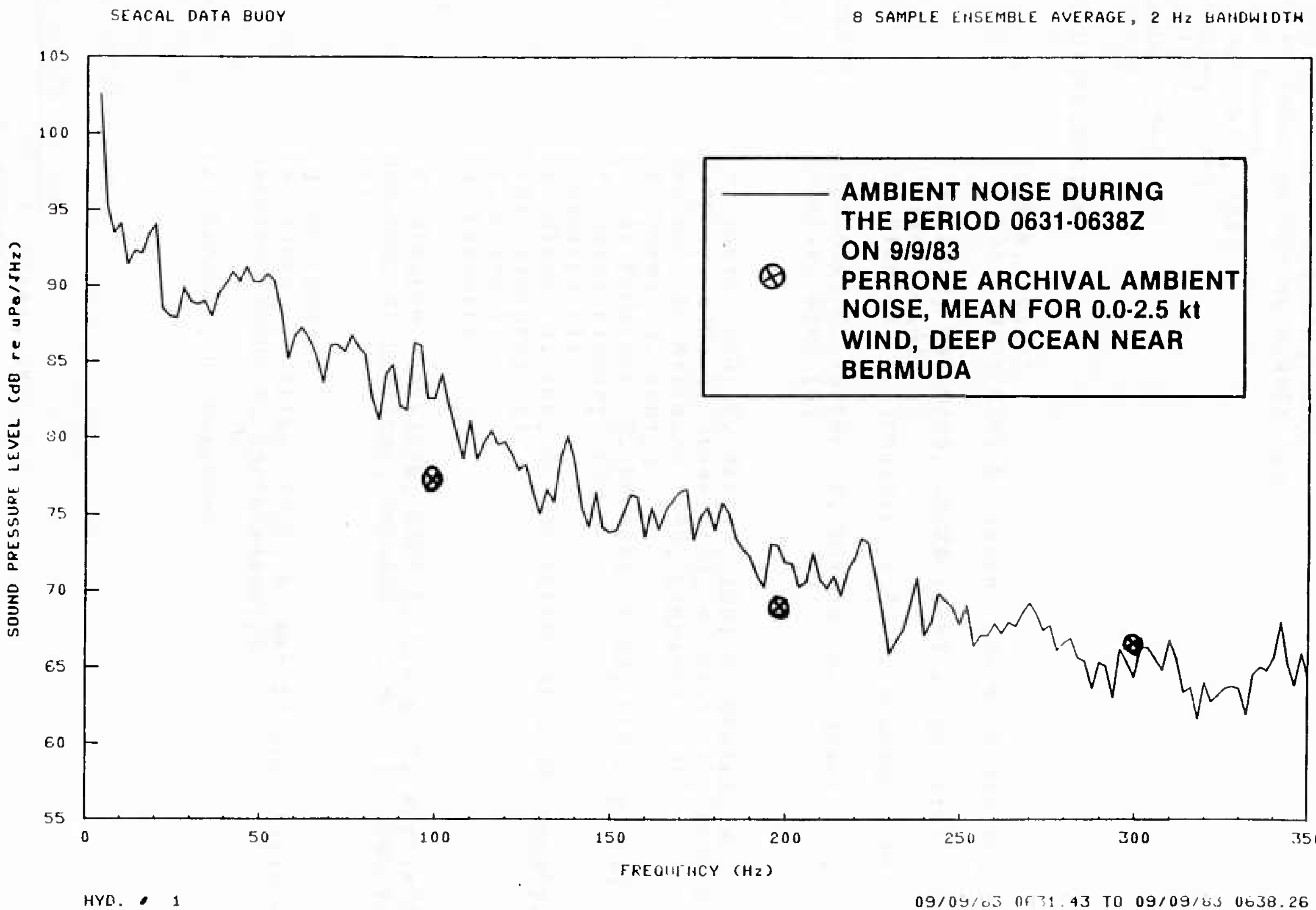
Ambient noise received on hydrophone #1 immediately prior to the CW tow 58 nmi west of SEACAL compared with archival measurements

Figure 16



Ambient noise spectra of the eight SEACAL hydrophones immediately prior to the CW tow 58 nmi west of SEACAL

Figure 17



Ambient noise received on hydrophone #1 during the period 0631-0638 Z on 9/9/83 compared with archival measurements

Figure 18

02232	B. LaCoe
03	D. Walters
0302	F. Filipini
039	D. Viccione
10	W. VonWinkle, F. DiNapoli
101	E. Eby, T. Cummings, P. Scully-Power, L. Maples, F. Weigle, R. Hasse
20	W. Clearwaters
32	J. Kingsbury
3211	J. Fay, D. Kennedy, A Lesick, J. Lau, N. Owsley, G. Swope
3212	J. Ferrie, J. Ianniello, R. Kneipfer, D. Tagliaferri
3213	L. Ng, A. Theodorau
3232	D. Abraham, G. Connolly Jr., G. Delacruz, J. Marsh, J. Mingrone
3233	S. Ko
3292	A. Ellinthorpe
33	L. Freeman
33A	B. Cole, P. Herstein (3), S. Santaniello, M. Johnson, M. Ricciuti (2)
33A1	G. Mayer, J. Gallagher
33A2	LCDR J. Malay
33A4	CDR J. Moulson
33B2	R. Soccoli
33B3	D. Counsellor
33C	W. Hay, J. Hanrahan, R. LaPlante (3)
33C6	LCDR W. Sander
3301	T. Bateman
3302	P. Cable
331	R. Boivin
3311	W. Hazard, R. Nadeau, S. Cox, D. DiTullio, P. King (5), A. Moorcroft, B. Wardle, T. Beaudoin
3312	A. George, M. Hundt, R. MacDonald
3313	J. Gregor, E. Harris
3314	C. Carter, R. Dwyer, A. Nuttall
332	C. Brown, R. Radlinski
3321	W. Konrad
3322	W. Birtcher, D. Brown, R. Malone, R. Noble, T. Whitaker, P. Seamen
3323	H. Ware, R. Hersh, H. Phelps, Jr.
333	W. Schumacher
3331	M. Fecher, J. Gorman, D. Browning, J. Chester, R. Dullea, S. Herskovitz, P. Koenigs, R. Nielsen, C. Perry, W. Roderick, A. Saenger, J. Syck
3332	R. Deavenport, B. Dedreux, D. Lee, H. Sternberg, D. Thomson, H. Weinberg
3343	R. Wilkinson
3422	E. Soderberg
363	D. Short
3643	P. Mello
38	J. Kyle,
3824	J. Visneuski
3844	R. Welsh, R. Rumpf (2)
413	J. Archer, F. Eno

601	T. Bell
701	R. Streit
73	D. Quigley

INTERNAL COPIES - 139